Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **APR 2008**	2. REPORT TYPE	3. DATES COVERED **00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE **Enhanced Field Emission Properties from Carbon Nanotube Emitters Grown on NiCr Alloy Surfaces with Grain Boundary Effect**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **ELORET Corporation,NASA Ames Research Center,Moffett Field,CA,94035**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002087. Proceedings of the 2008 IEEE International Vacuum Electronic Conference (9th) (IVEC 2008) Held in Monterey, CA on April 22-24, 2008. U.S. Government or Federal Rights License

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**2**	

21.2: Enhanced Field Emission Properties from Carbon Nanotube Emitters Grown on NiCr Alloy Surfaces with Grain Boundary Effect

Setha Yim,[1,2] Riichiro Ohta,[1,3] Jessie L. Killian,[4] Nathaniel B. Zuckerman,[1] Emily Allen,[2] and Cattien V. Nguyen.[1,*]

[1]ELORET Corporation, NASA Ames Research Center, Moffett Field, CA, 94035; [2]Department of Chemical and Materials Engineering, San Jose State University, San Jose, CA 95192; [3]University Affiliated Research Center, University of California, Santa Cruz, NASA Ames Research Park, Moffett Field, CA, 94035; [4]Department of Chemistry, San Jose State University, San Jose, CA 95192; *cattien.v.nguyen@nasa.gov

Keywords: carbon nanotube; field emission; segregation; 80/20 and 70/30 NiCr metal alloys; auger elemental mapping; grain boundary effect.

Carbon nanotubes (CNTs) are known to have exceptional field emission properties such as low turn-on voltage and high current density. Nilsson et al. reported that field emission properties depend highly on the density of the CNT films [1]. The CNTs must have low density in order to minimize electrostatic field screening from neighboring nanotubes. At the same time, the CNT films must have a high number of emitting sites to achieve a desirable current density. Recently, the direct growth of CNTs on metal alloys containing Ni, Cr, and Fe has been shown to be an attractive alternative for fabrication of CNT emitters without requiring a metal catalyst deposition step [2]. Herein, we report the field emission properties of multi-walled carbon nanotube (MWNT) films grown on polished smooth 80/20 and 70/30 NiCr surfaces by thermal chemical vapor deposition. We show that 80/20 NiCr surfaces prohibit growth of MWNTs at the grain boundaries [3], resulting in a lower turn-on field in comparison to a continuous MWNT film obtained with 70/30 NiCr substrates.

We reported previously on the field emission properties of MWNT films grown as pillars with 50 μm diameter based on a micropatterning technique [4]. Figure 1a shows the I-V curves for MWNT films grown on 80/20 and 70/30 NiCr alloys, which exhibit very distinct turn-on fields of 1.3 V/μm and 3.6 V/μm, respectively. The 80/20 NiCr alloy reveals a discontinuous film with MWNT islands, where MWNTs are not observed in areas around the grain boundary. In contrast, the 70/30 NiCr alloy shows a continuous film and a higher turn-on field (SEM image in Figure 1c). We attribute the lower turn-on field for the 80/20 NiCr sample to less field screening effects from lower density films, with a higher number of emission sites at the edge of MWNT islands close to the grain boundaries.

We utilize Auger electron spectroscopy (AES) elemental mapping and depth-profiling techniques to investigate the influence of the NiCr substrates on growth behavior. AES elemental mapping of the NiCr surface of both compositions reveal high Ni content at the inner grain surface and segregation of Cr and O to the grain boundary after a high temperature annealing process at 750°C, similar to the growth conditions for MWNTs. Less segregation of Cr and

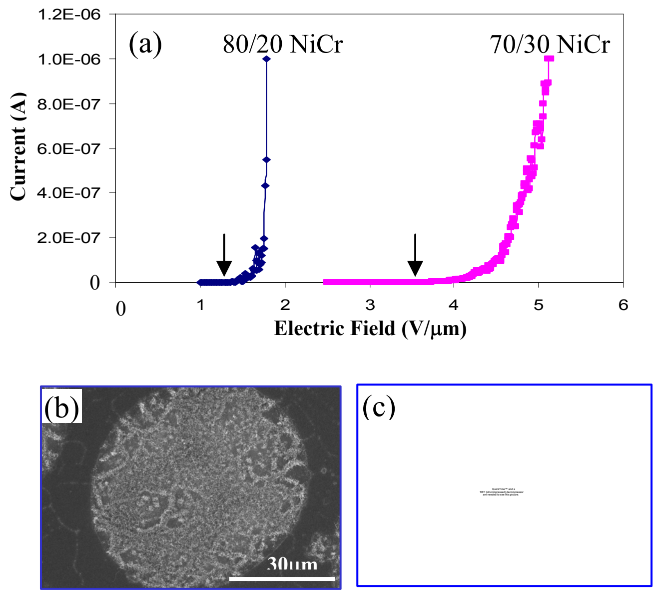

Figure 1. (a) Field emission I-V curves of 80/20 and 70/30 NiCr alloys, (b) SEM image of 80/20 alloys with grain boundary effect, (c) SEM image of 70/30 alloys showing a continuous film, without grain boundary effect. The turn-on field is defined at an emission current of 1nA.

O, with grain boundary width of about 1μm, is observed in the 70/30 alloys. In comparison, the 80/20 alloys reveal much larger areas of Cr oxide segregation at grain boundaries (Figure 2). The Ni-rich regions at the interior of the grains are directly correlated to areas of MWNT growth, as evidenced in the 80/20 NiCr alloy shown in Figure 3, whereas Cr oxide surface areas at the grain boundary appear to inhibit MWNT growth. It is interesting to point out that AES depth profiles of both 80/20 and 70/30 NiCr alloys reveal that the Ni-regions at the inner grains have a subsurface Cr and O enrichment.

In this paper, we demonstrate enhanced field emission properties from MWNT emitters grown directly on the 80/20 NiCr alloy surface due to the grain boundary effect. The elemental segregation was clearly demonstrated by AES elemental mapping, where Cr and O surface segregation inhibited MWNT growth. The potential for this simple process is that it may be employed for fabricating CNT emitters without

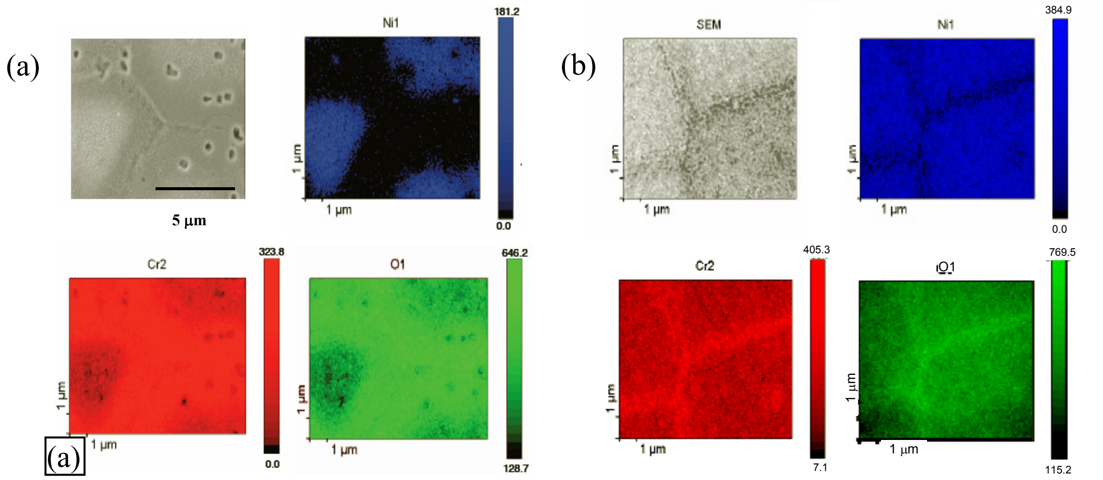

Figure 2. AES elemental mapping of thermally annealed (a) 80/20 and (b) 70/30 NiCr alloys.

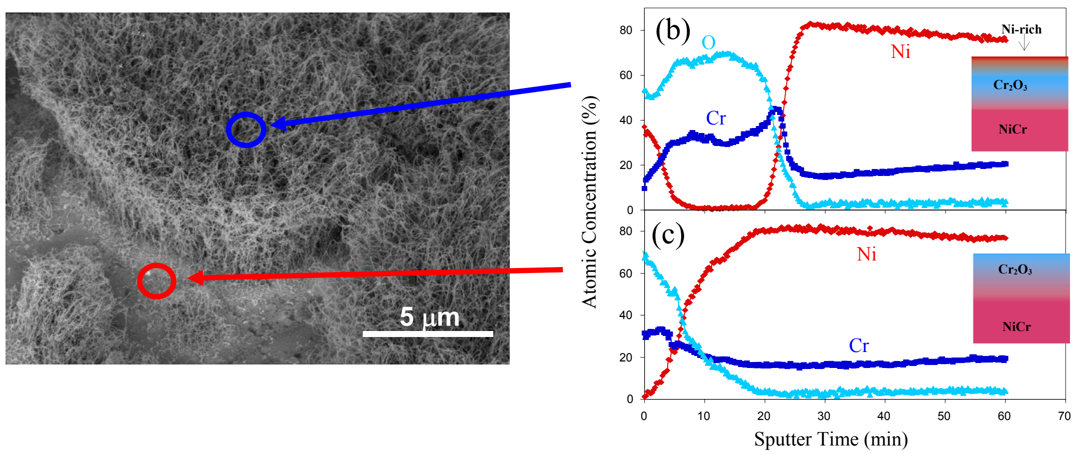

Figure 3. (a) SEM micrograph of selective growth of MWNTs on 80/20 alloy surface, (b) AES depth profile at Ni-rich grain interior region, and (c) at the grain boundary.

requiring any metal deposition step nor microlithography process in order to minimize the field screening effect.

References

1. Nilsson, L., O. Groening, C. Emmenegger, O. Kuettel, E. Schaller, and L. Schlapbach, "Scanning Field Emission from Patterned Carbon Nanotube Films," *Appl. Phys. Lett.*, Vol. 76, pp. 2071-2073, 2004.
2. Talapatra, S., S. Kar, S.K. Pal, R. Vajtai, L. Ci, P. Victor, M.M. Shaijumon, S. Kaur, O. Nalamasu, and P.M. Ajayan, "Direct Growth of Aligned Carbon Nanotubes on Bulk Metals," *Nature Nanotechnol.*, Vol. 1, pp. 112-116, 2006.
3. Yim, S., R. Ohta, N.B. Zuckerman, J.L. Killian, C. Hitzman, E. Allen, M. Meyyappan, and C.V. Nguyen, "Elemental Segregation on Surface of NiCr for the Direct Growth of Carbon Nanotubes: Grain Boundary Effect," *J. Am. Chem. Soc.*, submitted, 2007.
4. Killian, J.L., N.B. Zuckerman, D.L. Neimann, B.P. Ribaya, M. Rahman, R. Espinoza, M. Meyyappan, and C.V. Nguyen, "Field Emmission Properties of Carbon Nanotube Pillar Arrays," *J. Appl. Phys.*, in press, 2008.